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EXAMPLE OF INTERACTION EFFECTS IN TRANSDUCER ARRAYS. PART III.(U)

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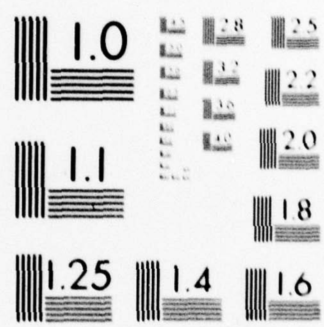

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U. S. Navy Underwater Sound Laboratory
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EXAMPLE OF INTERACTION EFFECTS IN TRANSDUCER ARRAYS. PART III.

by

(10) C. H. Sherman

(11) 25 Sep 62

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INTRODUCTION

In two previous memoranda ~~(references (a), (b))~~ an attempt was made to investigate acoustic interaction effects in a simple array of small elements (circular pistons with ka = 1/2). It was found that very significant interaction effects existed for elements of this size. Other experience with arrays of larger elements has suggested that the interaction effects are far less significant when the element size is greater. In the present work we seek some quantitative information about how large the elements must be to avoid the most drastic interaction effects. Rusby ~~(reference~~ (c)), after considerable experimental work with certain arrays of small elements, concluded that the element size must be less than about one-third wavelength ($ka < \pi/3$) for the interactions to have their most drastic effects. We will find results in general agreement with this conclusion.

Pi

CALCULATIONS

Further calculations have been made for the seven piston array described in reference (a). The seven pistons are arranged in a hexagonal pattern with symmetry such that when all pistons are driven with the same force there are only two different piston velocities. Here the ratio of the magnitude of the central piston velocity to the magnitude of an outer piston velocity (U_1/U_2) has been calculated as a function of the ka of an individual piston for close packing of the array (d/2a = 1) and for three values of the internal mechanical resistance. The same quantity is shown in Figure 4 of reference (a) as a function of d/2a, i.e., as a function of array packing. As in reference (a), we specify values of internal mechanical reactance appropriate to velocity resonance of an isolated transducer. Thus, results presented as a function of ka are to be interpreted as being a function of the radius a at the frequency of velocity resonance.

Using the equations from reference (a) we find

$$\frac{U_1}{U_2} = \left| \frac{R_M + R_{11} - 4R_{12} + 2R_{24} + R_{25} + i(2X_{24} + X_{25} - 4X_{12})}{R_M + R_{11} - R_{12} - iX_{12}} \right| .$$

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This quantity is given in Figure 1 as a function of ka for $R_M / R_{11} = 0.11$, 0.43 and 1.00

In this particular array with close packing the various piston center-to-center separations are $d_{12} = 2a$, $d_{24} = 2\sqrt{3}\,a$, $d_{25} = 4a$. When ka becomes very large the various kd_{ij} become very large and all the mutual resistances and reactances approach zero. Thus, we see that

$$U_1/U_2 \longrightarrow 1 \,, \qquad \text{for large ka.}$$

This behaviour for large ka, which would be the same for any array, is illustrated in Figure 1. Figure 1 also shows that for the particular array under discussion U_1/U_2 does not differ greatly from its limiting value of unity when ka exceeds 1.2 - 1.5.

As ka approaches zero the mutual reactances will become much greater than the mutual resistances and

$$\frac{U_1}{U_2} \longrightarrow 4 - 2\,\frac{X_{24}}{X_{12}} - \frac{X_{25}}{X_{12}} \,.$$

The mutual reactances will then be inversely proportional to kd_{ij}, and we get

$$\frac{U_1}{U_2} \longrightarrow 4 - 2\left(\frac{2}{2\sqrt{3}}\right) - \frac{2}{4} = 2.34$$

This result, which is a special property of this array, was used to plot the point at ka = 0 in Figure 1.

DISCUSSION

The ratio U_1/U_2 is a useful measure of the importance of the interactions since transducer damage due to widely differing velocities is probably the most drastic interaction effect. When this ratio is near unity, the interactions may still cause large variations of radiation impedance, but they will not be likely to result in transducer damage. We see from Figure 1 that this ratio is near unity for ka greater than 1.2 - 1.5, which is in general agreement with Rusby's conclusion. Figure 1 also shows that this conclusion does not depend strongly on the internal mechanical resistance, although the importance of the interactions for smaller ka does depend strongly on this resistance.

Rusby's work, as well as the present work, is based on particular arrays, but, since both are in reasonable agreement, it seems likely that a ka greater than 1.2 - 1.5 will prevent the most serious interaction effects in most cases.

Most of the calculations required for Figure 1 were performed by Robert J. Almeida.

C. H. Sherman

C. H. Sherman
Physicist

LIST OF REFERENCES

(a) J. F. Atwood, C. H. Sherman, "Example of Interaction Effects in Transducer Arrays", USL Technical Memorandum No. 912-20-62, 1 March 1962.

(b) J. F. Atwood, "Example of Interaction Effects in Transducer Arrays: Part II", USL Technical Memorandum No. 912-44-62, 25 May 1962.

(c) J. S. M. Rusby, "An Investigation of the Total Radiation Impedance of Rigid Piston Sound Sources in Arrays, Part V", Admiralty Research Laboratory, Teddington, Middlesex, ENGLAND, September 1961.

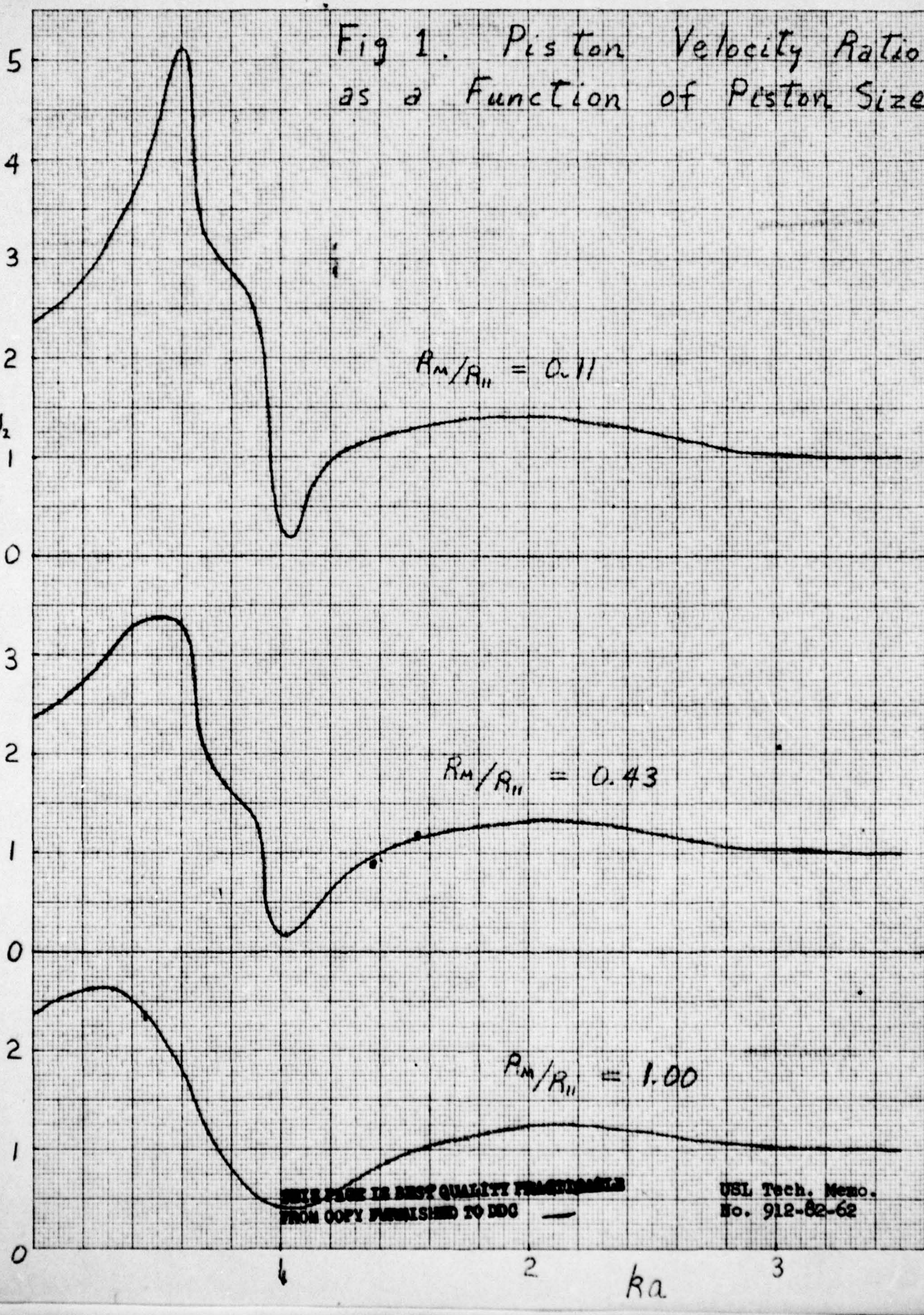

Fig 1. Piston Velocity Ratio as a Function of Piston Size

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